

# Assessing the Health and Performance Risks of Carbon Dioxide Exposures

JT James, VM Meyers, D Alexander

Habitability and Environmental factors Division  
and Space Medicine Division, NASA Johnson  
Space Center

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# Disclosure Information

*82<sup>nd</sup> Annual Scientific Meeting*

*John T. James*

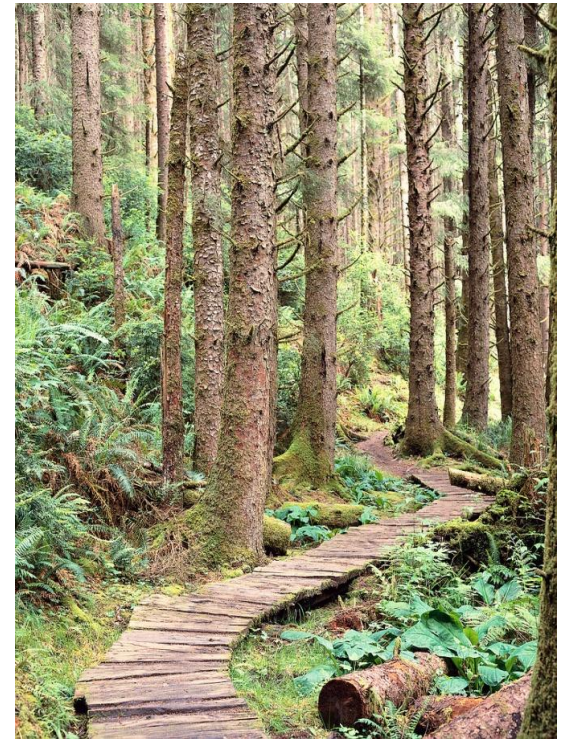
I have no financial relationships to disclose.

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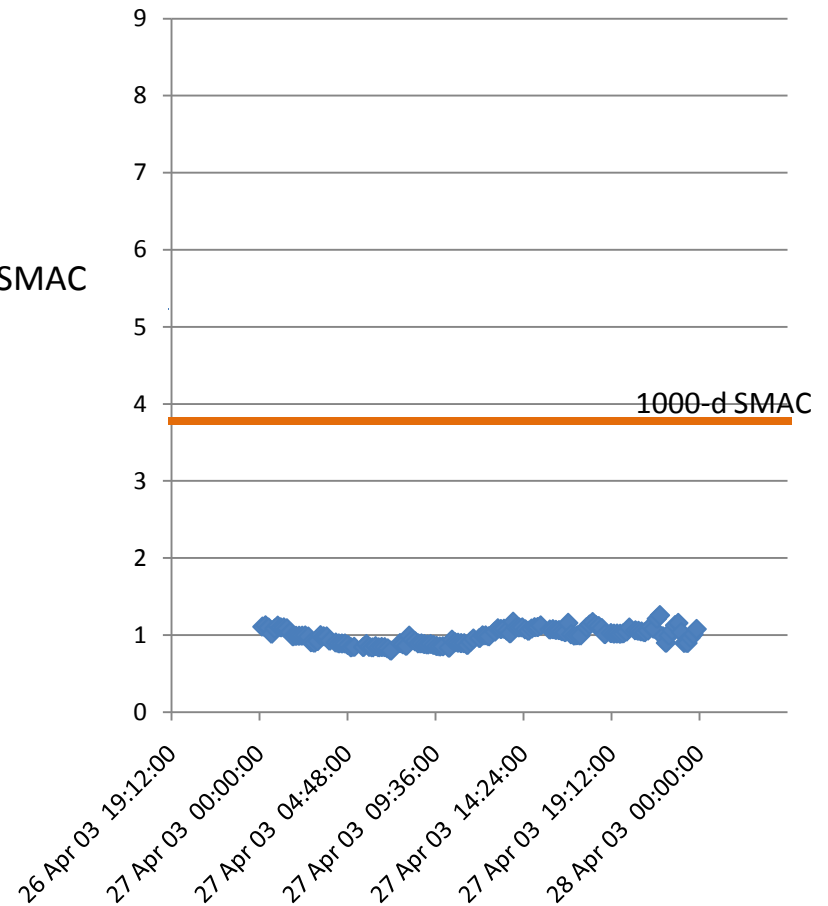
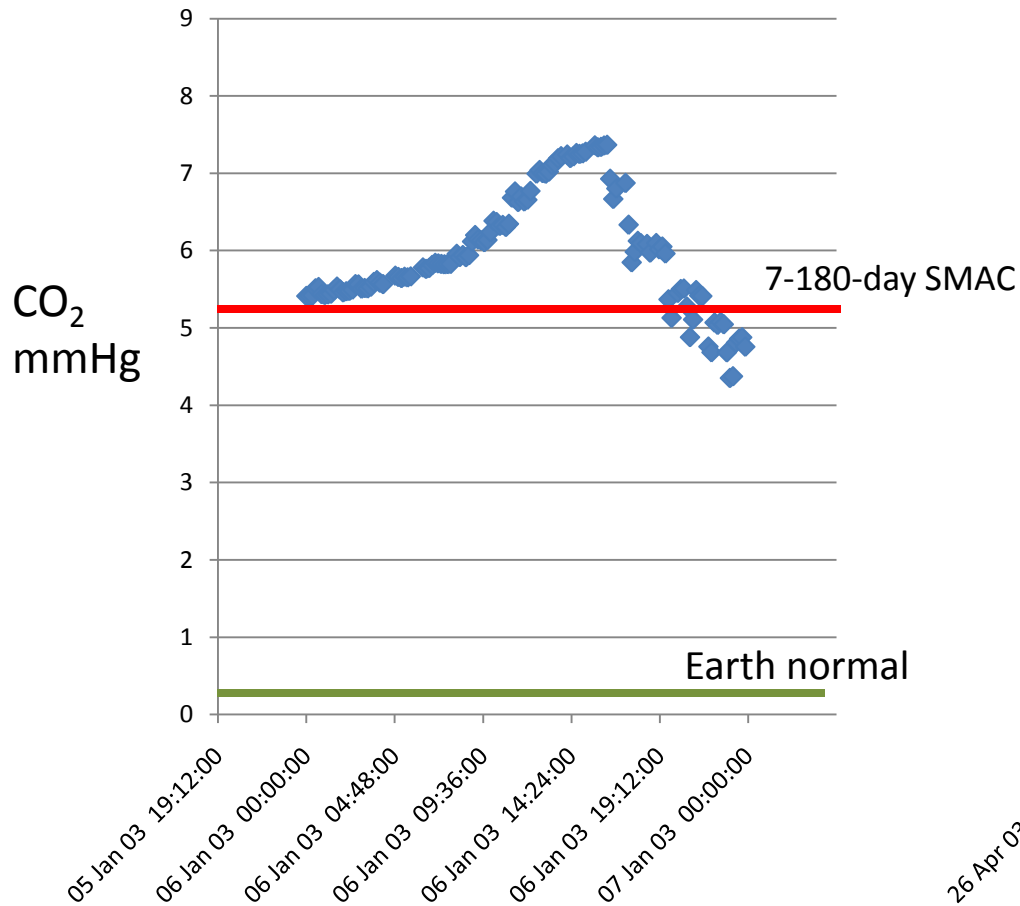


# Pathway

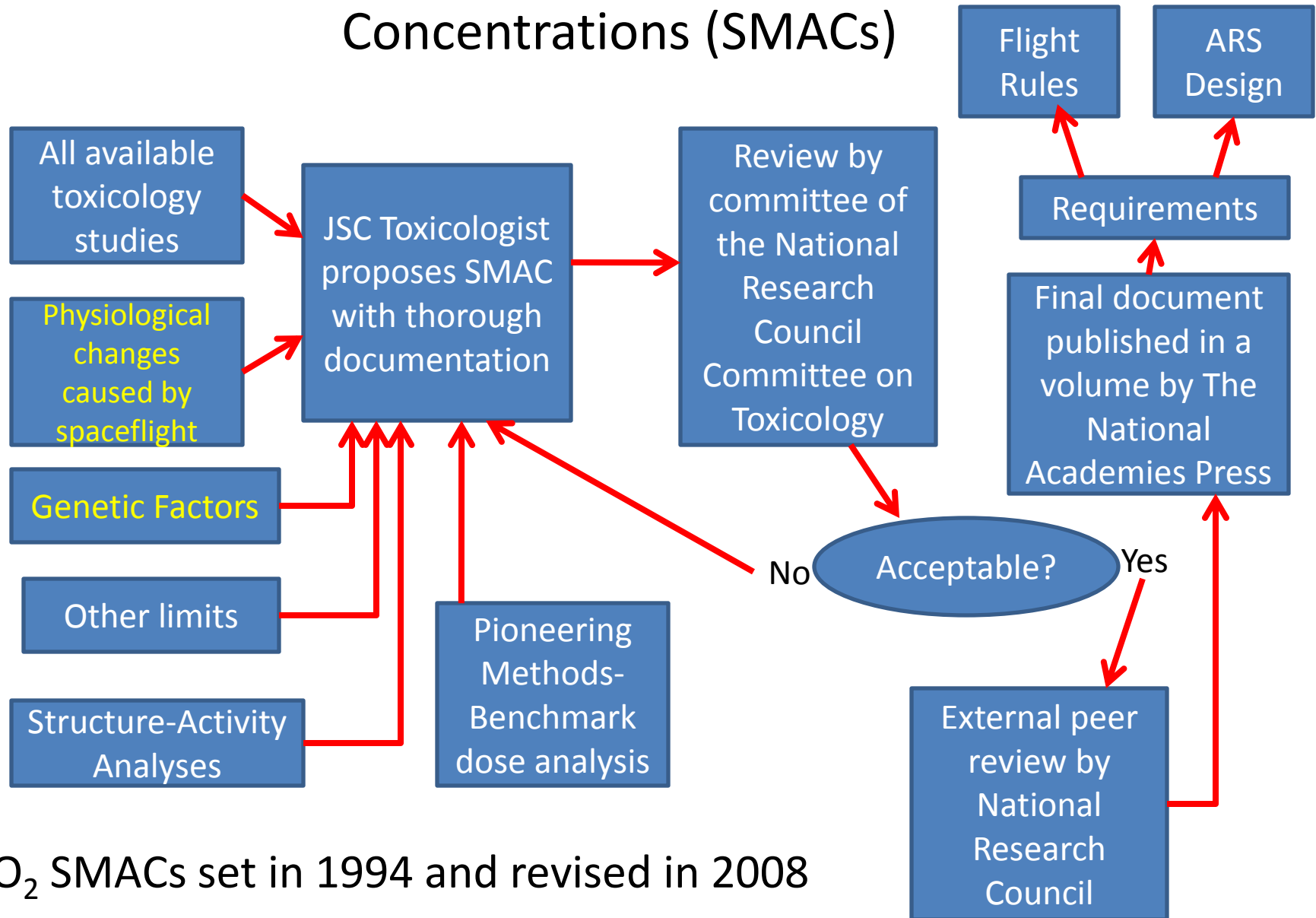
- **Risk**: Exposures to CO<sub>2</sub> during spaceflight
- **Risk Management**: Spacecraft Maximum Allowable Concentrations (SMACs)
- **Reality**: Current ISS status with CO<sub>2</sub>
- **Revision**: Attempts to associate elevated CO<sub>2</sub> with acute adverse effects
- **Revision**: Attempts to associate sustained and elevated CO<sub>2</sub> levels with adverse effects
- **Selectivity**: Thoughts on genetic differences
- **Transition to Operations**: flight rules



# Risk: 24-hr exposures to CO<sub>2</sub> during spaceflight from MCA Data

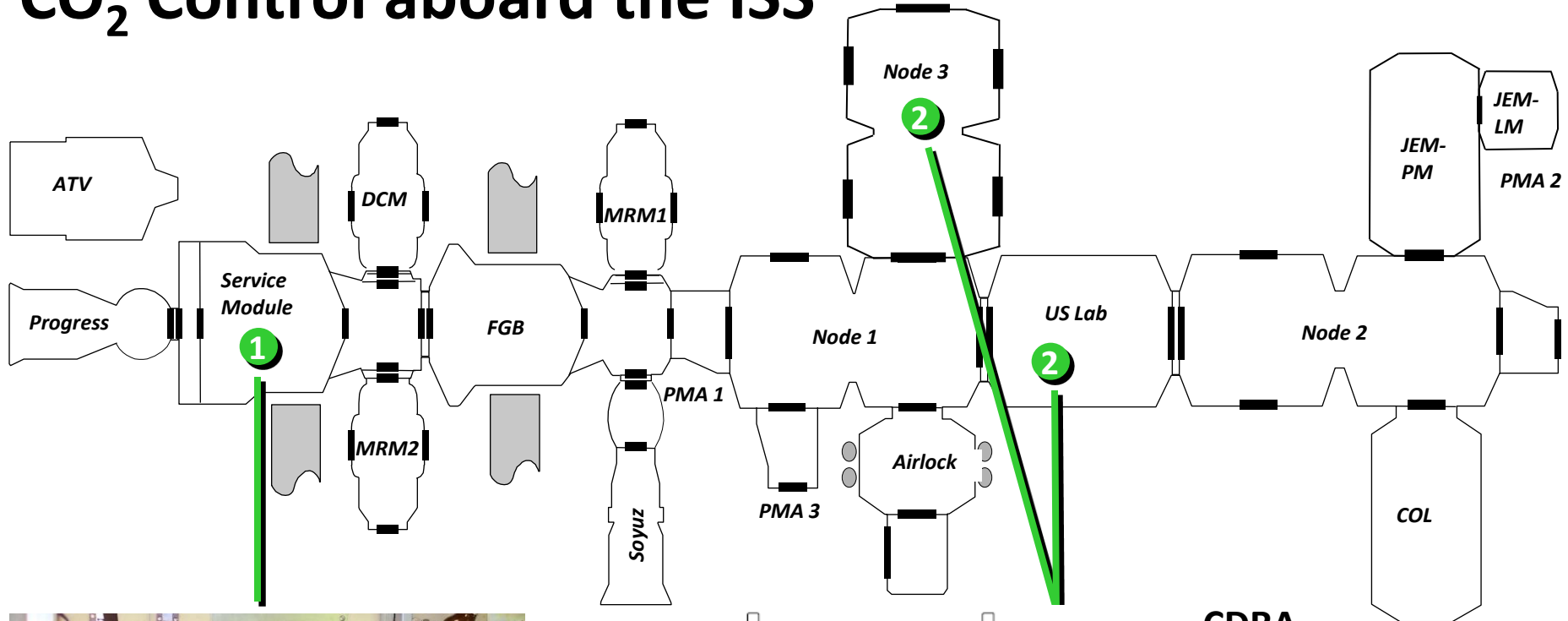


# Risk Management: Spacecraft Maximum Allowable Concentrations (SMACs)

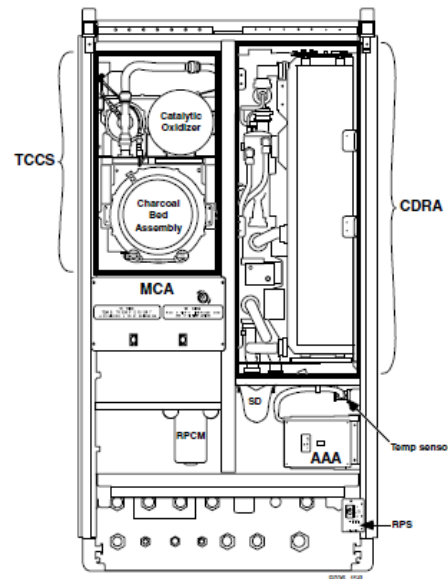


CO<sub>2</sub> SMACs set in 1994 and revised in 2008

# CO<sub>2</sub> Control aboard the ISS



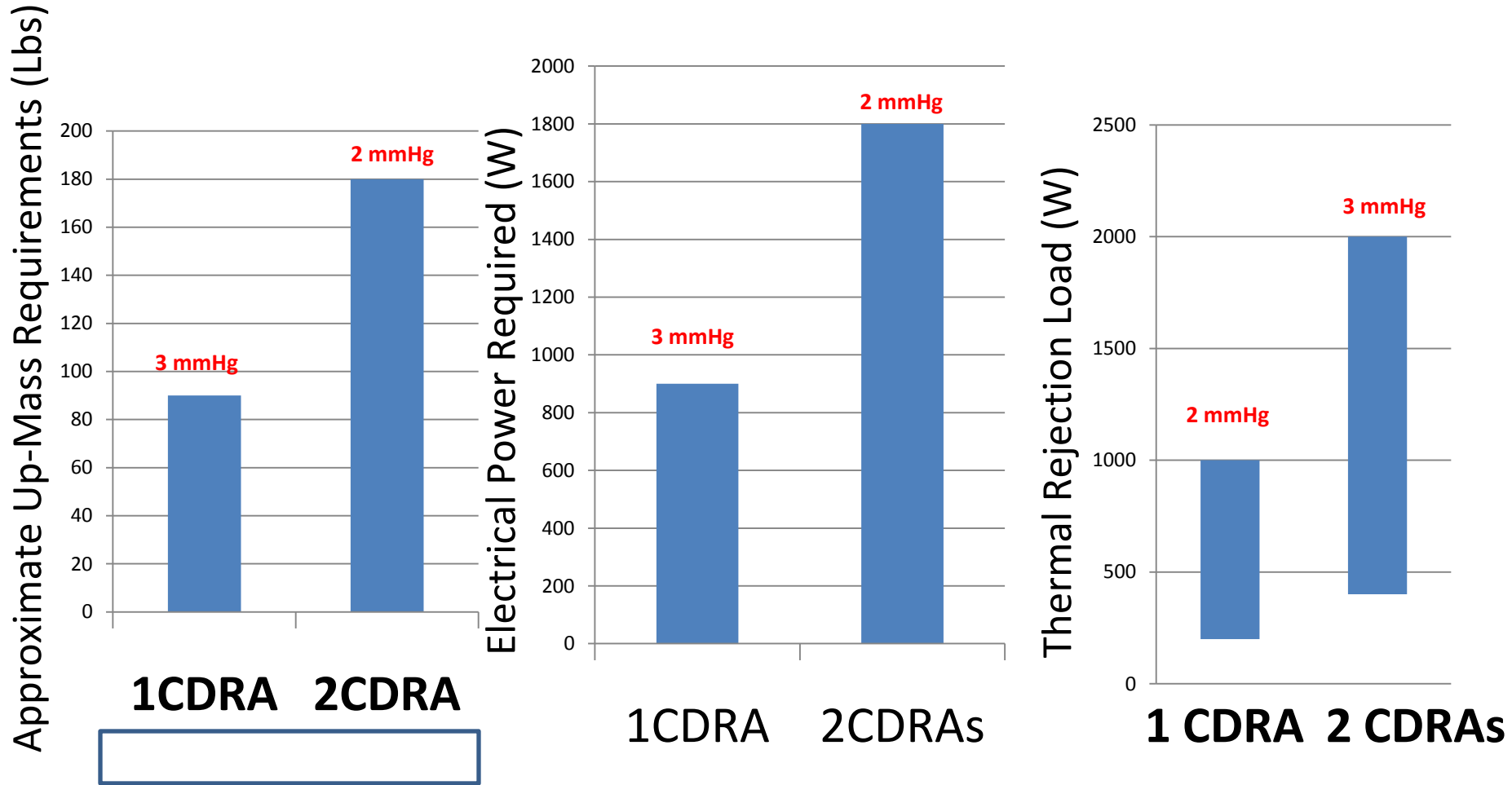
Vozdukh



CDRA



# Reality: Current ISS status with CO<sub>2</sub>: 6 crewmembers and Vozdukh operating





# Revision: Attempts to associate elevated CO<sub>2</sub> levels with acute adverse effects

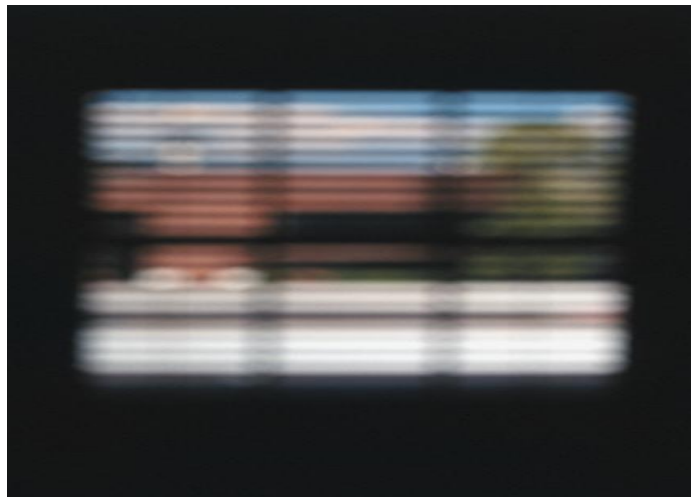
- Behavioral Effects-WinSCAT
  - Mathematical Processing
  - Continuous Performance Task
  - Code Substitution Delayed Recognition
  - Match to Sample
  - Looked at total score, sub-scores, and changes in these
  - Compared to CO<sub>2</sub> averages and peak levels 1 and 7 days before
- Headaches
  - 12 Identified from private medical conferences in ~10 years
  - Searching call down records
- Visual disturbances





# Revision: Attempts to associate elevated CO<sub>2</sub> with lasting adverse effects

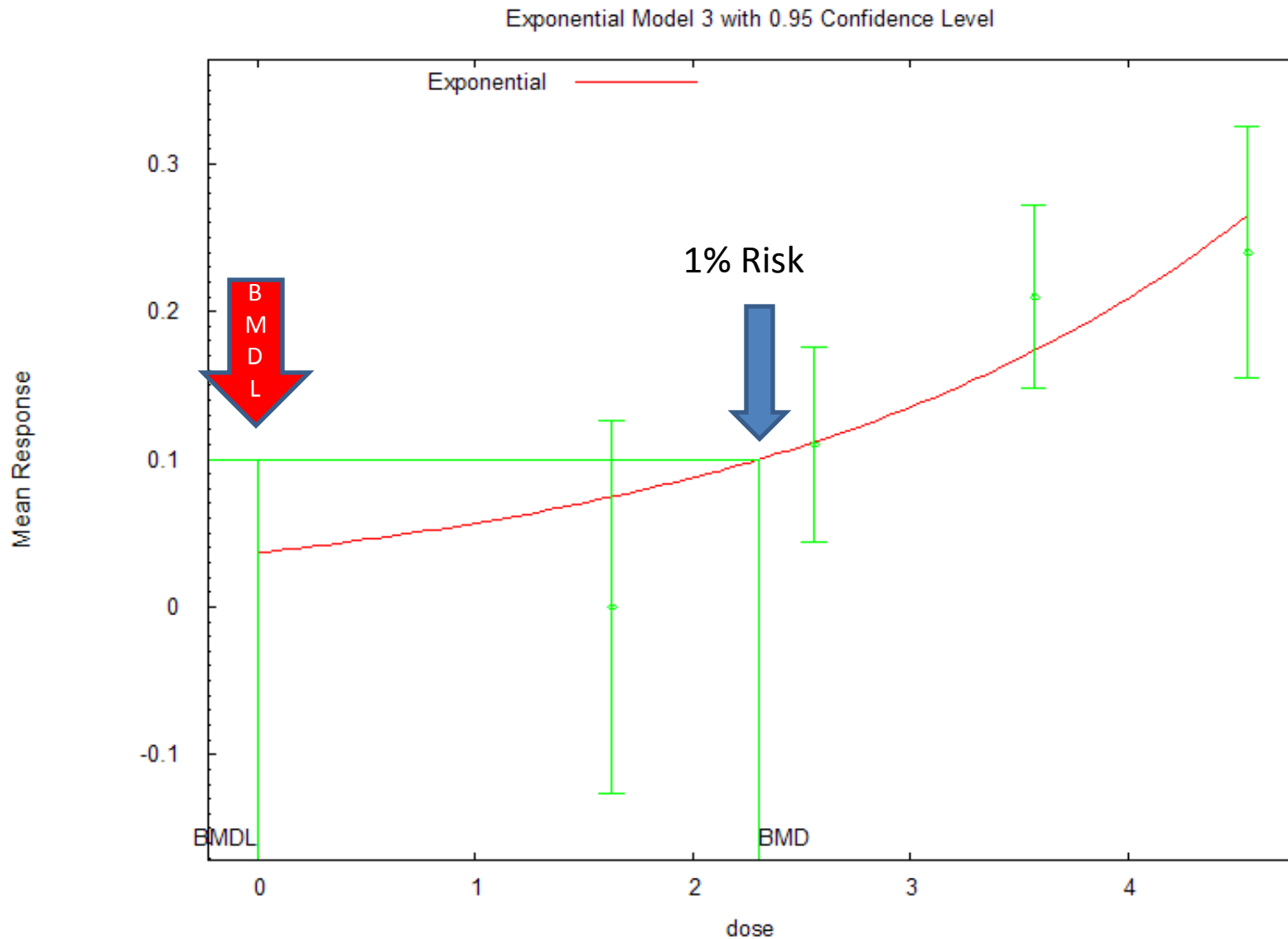
- Visual changes are common during prolonged missions
- Lasting Visual changes have been reported in a few crewmembers after flight



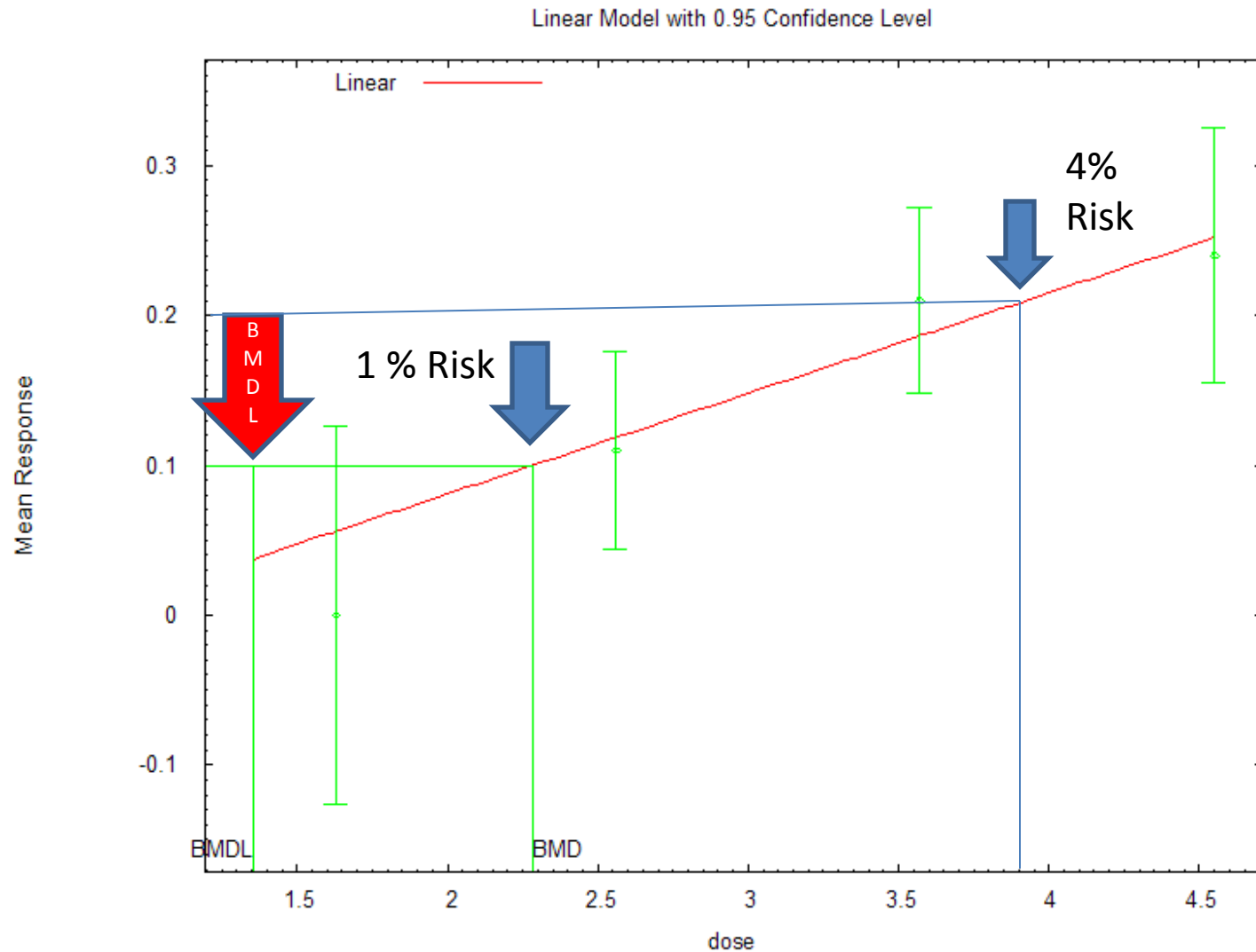
# Data Sorting: Headaches vs. Incidence in CO<sub>2</sub> Bands

- Raw incidence in four bands (% of PMCs)
  - <2 mmHg
  - 2-3 mmHg
  - 3-4 mmHg
  - >4 mmHg
- Use arcsine of square root of the decimal % to apply benchmark dose analysis
- Calculated average CO<sub>2</sub> level in each band
- Tried 5 benchmark dose models (3 'worked')

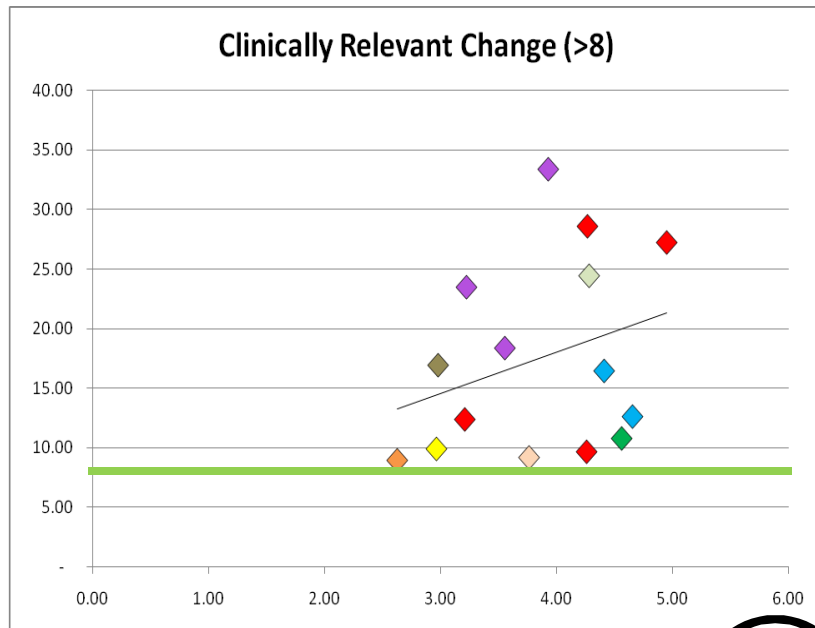
# Headache Risk & 24-hr Average CO<sub>2</sub>



# Headache Risk & 24-hr Average CO<sub>2</sub>

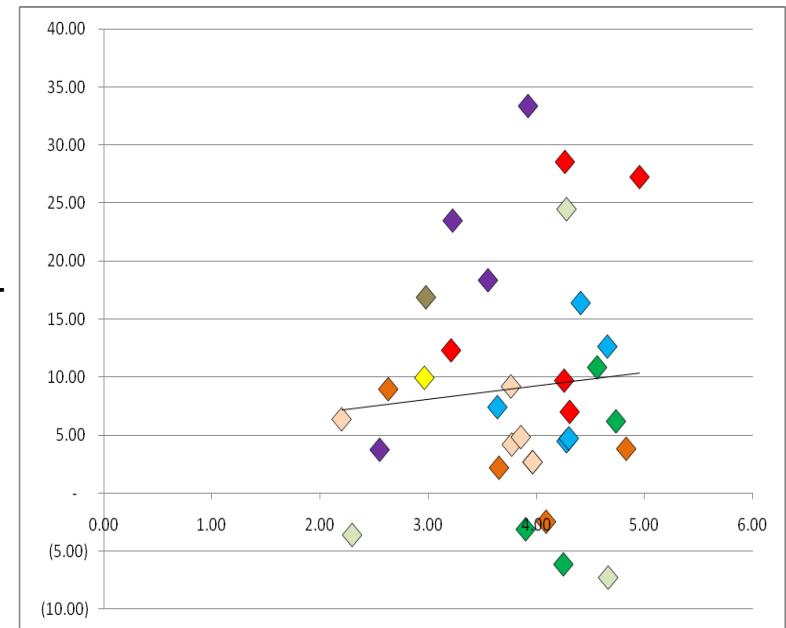


# $\Delta$ Continuous Performance Task



CO<sub>2</sub> mmHg

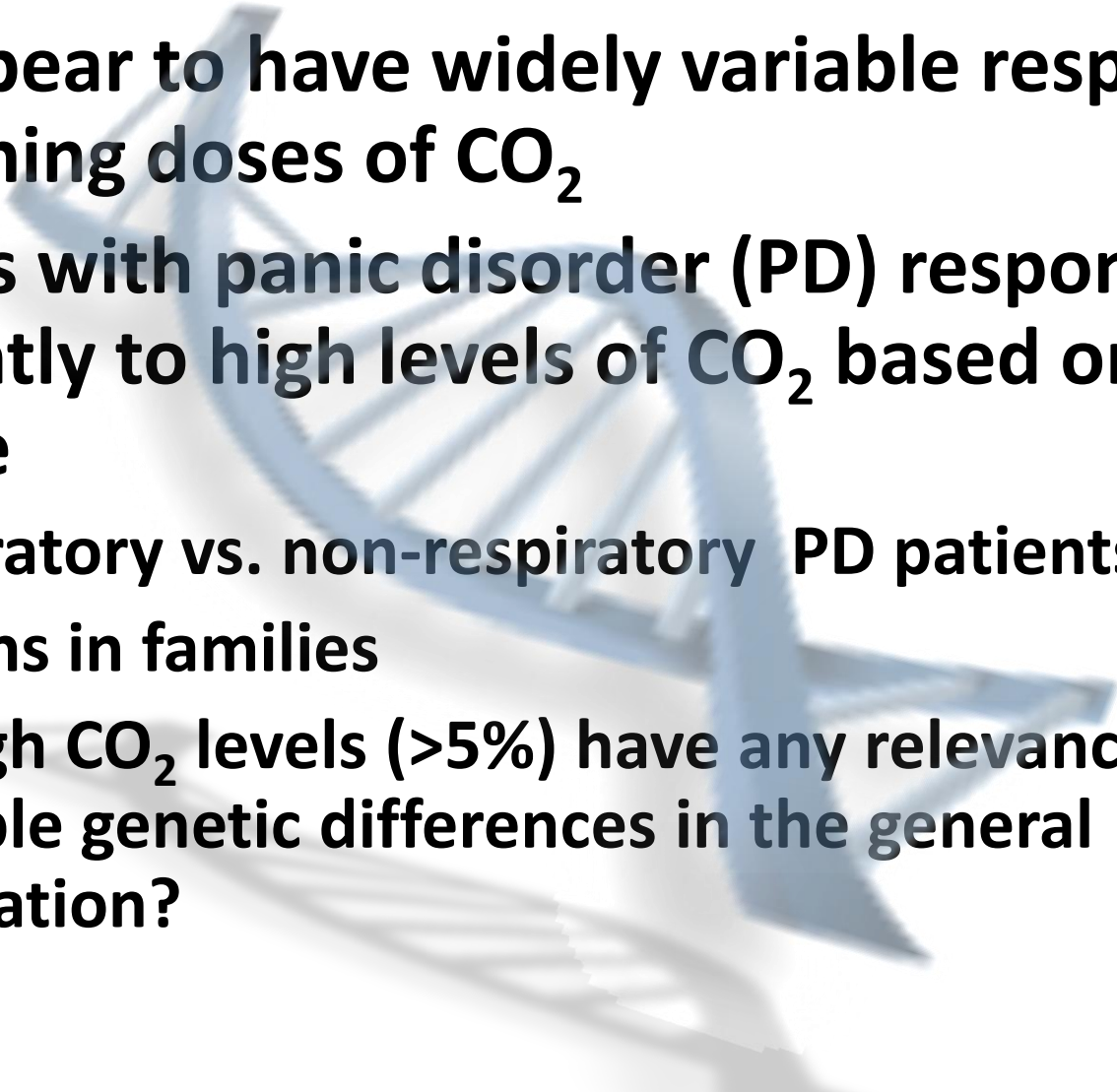
↑  
Δ CPT



CO<sub>2</sub> mmHg



# Selectivity: Semi-random thoughts on genetic differences

- Pigs appear to have widely variable response to stunning doses of CO<sub>2</sub>
  - Humans with panic disorder (PD) respond differently to high levels of CO<sub>2</sub> based on subtype
    - Respiratory vs. non-respiratory PD patients
    - PD runs in families
    - Do high CO<sub>2</sub> levels (>5%) have any relevance to possible genetic differences in the general population?
- 

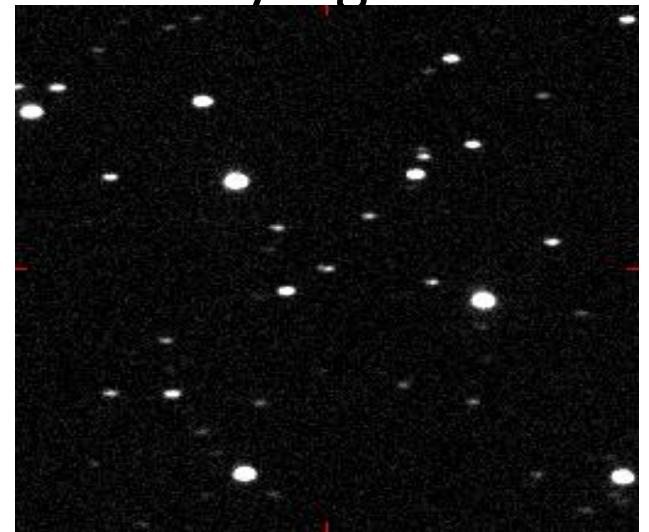
# Transition to Operations: flight rules

- Current flight rule requires more drastic action as CO<sub>2</sub> levels rise
- In practical terms we try to operate with CO<sub>2</sub> below 4 mmHg
- Management also depends on any symptoms presumed to be associated with CO<sub>2</sub> exposure
- Hardware failures, local pockets, and large crew size can pose a challenge to manage CO<sub>2</sub> to 3 mmHg or less



# Observations & Recommendations

- Aboard ISS we may be faced with some hard choices between management of crew health risks and practical CO<sub>2</sub> management
- Explore differences in response to CO<sub>2</sub> levels in the range from 2-8 mmHg using ground-based model (bedrest?) → identify genetic differences
- Perform blind challenges aboard the ISS to determine changes in susceptibility on orbit in the range from 2-8 mmHg. Use highly sensitive tests to identify significant effects.
- We must have a clear grip on CO<sub>2</sub> issues before we launch human exploration missions.



# Acknowledgments

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